Prime Movers for Electric Power Plants

J. S. Smalley

1907

621.1
Sm 1

ARMOUR
INST. OF TECH. LIB.
CHICAGO.

Illinois Institute
of Technology
Libraries

AT 94
Smalley, J. S.
Selection of prime movers
for electric power plants

937
Z6

SELECTION OF PRIME MOVERS
FOR
ELECTRIC POWER PLANTS

A THESIS

PRESENTED BY

J. S. SMALLEY

TO THE

PRESIDENT AND FACULTY

OF

ARMOUR INSTITUTE OF TECHNOLOGY

FOR THE DEGREE OF

BACHELOR OF SCIENCE IN ELECTRICAL ENGINEERING

HAVING COMPLETED THE PRESCRIBED COURSE OF STUDY IN

ELECTRICAL ENGINEERING

1907

John E. Snow
Acting Director Elect. Eng. Dept.

ILLINOIS INSTITUTE OF TECHNOLOGY
PAUL V. GALVIN LIBRARY
35 WEST 33RD STREET
CHICAGO, IL 60616

621.1
Sm1

Conditions Governing Selection of Plant :-

Three 220 b.h.p. engine units direct-connected to 150 K.W. 250 volt D.C. generators. Factory load of 10 hours per day, 310 days per year, average load 300 K.W. Anthracite coal $5.00 and bituminous coal $3.00 per ton of 2000 lb. dilivered at plant. Water at one cent per 10000 lb. Cost of land not considered.

There are four principal types of prime movers available for powers of 200 b.h.p. and over. They are the reciprocating steam engine, the gas engine, the steam turbine and the hydro-turbine. In a few years it may be possible to add the gas turbine to the list but it is not yet on the market.

For the present treatment of the subject of theselection of prime movers we will consider only the reciprocating steam engine, the steam turbine and the gas engine using producer gas, because only in a few favored localities are water-power, natural gas or blast-furnace gas available.

In determining which form of prime mover to adopt for any given power installation the main consideration is reliability combined with low operating expense. This operating expense is not merely the cost of coal, water, wages etc. but includes the fixed charges on the plant such as interest on

19494

Conditions Governing Selection of Plant :-

Three 250 b.h.p. engine units direct-connected to 150 K.W. 250 volt D.C. generators. Factory load of 10 hours per day, 310 days per year, average load 300 K.W. Anthracite coal $6.00 and bituminous coal $3.00 per ton of 2000 lb. delivered at plant. Water at one cent per 10000 lb. Cost of land not considered.

There are four principal types of prime movers available for powers of 200 b.h.p. and over. They are the reciprocating steam engine, the gas engine, the steam turbine and the hydro-turbine. In a few years it may be possible to add the gas turbine to the list but it is not yet on the market.

For the present treatment of the subject of theselection of prime movers we will consider only the reciprocating steam engine, the steam turbine and the gas engine using producer gas, because only in a few favored localities are water-power, natural gas or blast-furnace gas available.

In determining which form of prime mover to adopt for any given power installation the main consideration is reliability combined with low operating expense. This operating expense is not merely the cost of coal, water, wages etc. but includes the fixed charges on the plant such as interest on

10164

initial investment, taxes, insurance and depreciation.

Thus we see that the selection of type of plant depends upon many different factors, most of which are antagonistic, so that our design is largely a series of compromises the ultimate aim of which is to get a horse-power hour as cheaply as possible consistant with reliability of service.

Further-more these factors vary greatly within themselves, depending to a large extent upon local conditions so that we can not select ane type of plant for any particular service and call it a standard through-out the country, but for any given installation we must investigate all the available types of plants with reference to the particular conditions involved, in order to make a suitable selection. Thus when coal is cheap it is folly to install, at heavy expense, a highly effecient steam plant because the increase in the fixed charges would more than offset the gain in fuel economy. However it is not strictly true that the fixed charges increase in a direct proportion as the efficiency of the prime movers is increased, because the lower steam consumption obtained decreases the boiler, feed-pumps, and coal conveyer capacity necessary and also the size of the boiler house required, but this advantage is offset because the more efficient

required, but this advantage is often overcome the more elastic capacity necessary and make the site of the nether house [illegible] the latter [illegible] time makes it increased, because the lower rate consumption increase in a direct proportion on the efficiency of the economy. However it is not strictly true that the fixed charges is the first charges nearly more than offset the gain in fuel economy, a highly efficient steam plant because the increased condition involved, it cannot be made a suitable selection available type of plants with reference to the particular for any given installation we must investigate all the relative and call it a standard throughout the country, but so that we can not adopt one type of plant for any particular themselves, depending to a large extent upon local conditions

Numberless these factors must greatly affect

how as cheaply as possible consistent with reliability of

service.

compromises the ultimate aim of which is to get a horse-power [illegible] no that one needs is largely a series of [illegible] upon many different factors, most of which are

Once we see that the selection of type of plant

initial investment, cause, increase one depreciation.

engines, demanding higher steam pressure, necessitate a more expensive type of boiler and heavier steam piping.

Thus we see thatthe factors entering into the determination of the most desirable type of plant for a given service in a given location bear a very complex relation to each other and for this reason the most satisfactory method of selecting a plant for any given set of conditions is to carefully estimate the fixed charges and running expense of all the types of plants that will fill the conditions and select the one withthe smallest operating expense provided it also has the required reliability. This is the method I have followed and my results have been placed in tabular form and are bound with this paper.

In table number will be found the estimated initial cost of five types of reciprocating steam engine plants, and two types of steam turbine plants of about the required capacity. This table represents a sort of general average taken from all the data obtainable.

Table number III is a complete estimate for the installation of an equivalent gas engine and producer station. For steam plants it is not a difficult matter to get definite data on the various parts that make up the complete plant because of the large volume of published material on the subject but with gas engine plants next to nothing has ever

employs two with gas engine plants must be working per cent
because of the large amount of publishing matter on the
data on the various parts that make up the complete plant
For steam plants it is not a difficult matter to get definite
installation of an advantageous engine and producer results.

Table number 24 is a complete estimate for the
the data obtainable.

There table represents a sort of general average taken from all
the types of steam turbine plants of about the required capacity, and
one of five types of hydro-electric units using plants, and
any one found with the paper.

In table number will be found the estimated installation
data followed and my results have been placed in tabular form
it also has the required reliability. This is the method I
without the one minute emergency operating expense provided
all the types of plants that will fill the conditions and
carefully estimate the fixed charges and running expense of
of selecting a plant for any given set of conditions is to
each other and for this reason the work absolutely method
service in a given location part a very complex relation to
determination of the most desirable type of plant for a given

Then we see thereby factors entering into the
expensive type of boiler and heater steel piping,
engines, consuming light, steam pressure, necessitate a more

been published as to costs of the various parts that make up the plant nor have I ever been able to find any complete data compiled in such a way that for a given plant capacity we could make a direct comparison between the engines and producer equipment furnished by the various manufacturers.

To supply this deficiency I have written directly to all the manufacturers of large gas engines and producers for definite data on their products and the results of my correspondence is tabulated in tables number I and II.

The following firms could not furnish apparatus of the size required :

Otto Gas Engine Works, Philadelphia, Pa.
Maximum size of engine 140 b.h.p. single cylinder.

DuBois Iron Works, DuBois, Pa.
Maximum size of engine 150 h.p.

Jacobson Machine M'f'g'. Co. Warren Pa.
Maximum size of engine 55 h.p.

Miller Improved Engine Co. Springfield, Ohio.
Engines for natural gas only.

Wellman - Seaver - Morgan Co.
No gas producers large enough.

Allis - Chalmers Co. Milwaukee, Wis.
Smallest size gas engine 450 b.h.p.

Wile Power Gas Co. Rochester, N.Y.
Sent blue-prints of engine & producer but no data.

I was unable to get any word from the following firms

Westinghouse Machine Co. Pittsburg, Pa.
Pressure gas producers.

I was unable to get any word from the following firms

J.Thompson & Sons, Beloit, Wis.
Builders of gas engines and producers.

Weber Gas Engine Co. Kansas City, Mo.
Builders of gas engines and producers.

It should be distinctly understood however that the costs given in tables I and II are only the manufacturers estimates and that they are not to be taken as the lowest figure for which it is possible to purchase the apparatus. It is next to impossible to exactly determine the lowest figure for which such apparatus can be bought unless one is actually negotiating for the purchase of an engine or producer but some idea of the discount obtainable can be had by comparing the results as given in tables I and II with the figures used by a prominent firm of consulting engineers in estimating such work.

I have an unpublished estimate for a gas power station, with 200 b.h.p. units, made by Louis Immer & Co. (Gas engine experts of Cincinnatti Ohio) and in their estimate they place the cost of gas engines at $35.00 per b.h.p. and the complete cost of gas producer using bituminous coal at $20.00 per engine b.h.p. This I have every reason to believe is very near the actual cost for this size of units.

In order to get as near as possible to the actual cost of the engines and producers given in tables I and II I

Builders of gas engines and producers.

Weber Gas Engine Co., Kansas City, Mo.

Builders of gas engines and producers,

It should be distinctly understood however that the
course given in tables I and II are only the manufacturers
estimates and that they are not to be taken as the lowest
figure for which it is possible to manufacture the engines.

It is next to impossible to exactly determine the lowest
figure for which such operations can be bought unless one is
constantly negotiating for the purchase of machinery or
machinery but even then of the lowest obtainable can be had
by comparing the results as given in tables I and II with the
figures used by a few years time of constructing engineers
in estimating such work.

I have an unpublished estimate for a gas power
elevator, with 100 b.h.p. motor, used by Doyle Lumber Co.
(Gas engine experts of Cincinnati Ohio) and on their
estimate they place the cost of gas engines on the b.h.p. for
b.h.p. and the complete cost of the elevator using different
cost as $50.00 per engine b.h.p. This I have every reason to
believe is very near the second cost for this kind of units.

In order to get as near as possible on the actual
cost of the engines and producers given in tables I and II I

established a sort of factor by dividing $35.00 by the average cost per b.h.p. of the engines as given in tables . A similar factor was also obtained for the products.

Tables X ~~and~~ shows the calculated operating expense per year for each of the types of stations investigated. The results of these tables show clearly that the gas engine plant notwithstanding its higher initial cost can be operated at a lower cost per year than any of the steam plants and therefore this type of plant should be selected providing it can be shown to be thoroughly reliable.

No one thinks of questioning the reliability of the reciprocating steam engine and within the last few years the steam turbine has proved itself thoroughly reliable but there has always been more or less doubt in the minds of the laity reguarding the reliability of the gas engine. This is probably due to the fact that the large gas engine is of very recent origen and it is only within the last two or three years that its design has been brought to the refinement obtained in the steam engine practice. The early gas engines of large power was used on blast furnace gas and as they had not yet perfected a reliable means of removing the dust and as the old system of tube ignition was faulty, the engine did not prove very reliable and although the engine has now entirely outgrown these faults still many people continue to think of the gas engine as being

unreliable. As now designed the large gas engine and producer plant is equally as reliable as the steam engine and boiler plant as I will cite a few examples to show.

Philadelphia has a high pressure pumping station of 2400 horse-power, entirely operated by gas engines and the fire-underwriters have approved the installation and reduced the charges on insurance 25 cents per $100. A 300 b.h.p. Westinghouse gas engine similar to those used at the Philadelphia station has shown the following remarkable run under heavy load,

Total elapsed time	8472 hours.
Hours run	8230 "
" "	97%
Hours shut down (chargable to engine)	51 hours.
" " "	0.6%
Run without stopping	1157 hours.
" " " (24 hour days) ..	48 ds.,5 hrs.

Shut-down necessary to repair broken belt.

In a 500 h.p. pumping station a short distance from Pittsburg each gas engine unit operates 96 to 98% of the elapsed time being shut down only for a few hours on Sundays for inspection.

unreliable. We now designed the large gas engine our predecessor plant is usually as reliable as the steam engine and boiler plant as I will make a fair comparison in time.

Philadelphia has a high pressure gas, electric station of 2500 horse-power, entirely operated by gas engines and the three-cylinder type have improved the steadiness and reduced the charges on insurance 33 cents per $100. A 300 H.P. Worthington gas engine similar to those used at the Philadelphia station has proved the following reasonable run

Total elapsed time ..... 8412 hours.

" " ..... "

Hours shut down (duplicate to engine) 31 hours.

" " " ..... "

Shut-down necessary to repair broken belt.

In a 300 H.P. coupling station I short interval ... from fastening each gas engine unit operates 96 to 99% of the elapsed time having shut down only for a few hours on Sundays for inspection.

A 650 h.p. Westinghouse gas engine driving a gas conpressor in the Ohio Gas Fields has a record of 40 days (24 hr.) continous run under full load without mishap or deterioration.

Unusually severe conditions surround the Warren and Jamestown Street Railway system of 42 miles of road, half city and half interurban. A gas engine plant of two 500 h.p. units is operating this entire service without steam reserve. The following summary regarding this plant is made by Mr.J.R.Bibbins, in a paper presented before the "Engineers Society of Western Pennsylvania" June 5, 1906.

1. It has the ability to handle variable loads.
2. Effect of misfires negligible.
3. Regulation suitable for alternating current in parallel operation.
4. Automatic starting system sufficient for any emergency, unit can be started in less than 30 sec.
5. Oil and water consumption low.
6. Sufficient reliability for regular daily service.
7. Deterioation from wear quite normal.
8. General character of labor required is not above the ordinary.

The Boston Elevated Railway Co. has experimented

The Boston Elevated Railway Co. was incorporated

the ordinary.

3. (Seven) operators at labor required is not above

3. Sufficient reliability for regular daily service.

4. Uniform [illegible]

[illegible] must run be started in less than 30 sec.

1. All [illegible]

2. Operation [illegible]

3. Sufficient reliability for regular daily service.

4. Uniform [illegible]

parallel operation.

5. Magnetic switches for alternating current in

6. Most of machines [illegible].

7. It has low ability to handle variable loads.

"Engineers Society of Western Pennsylvania" June 5, 1909.

is made by Mr. J.H. Bliss, in a paper presented before the

800 h.p. units is expected this entire service without

local site and high reservoirs. A 40,000 h.p. engine of two

and Jamestown Steam Railway system of 43 miles of road,

interconnection.

(24 hr.) conditions run under full load without stopping or

connection in the Ohio Gas Fields has a record of 40 days

7 650 h.p. Westinghouse gas engine driving a 3ph

with gas power for supplying its outlying districts. For this purpose they built two stations of about 1700 h.p. each. One of them is equiped with Taylor pressure gas producers and Korting two-cycle gas engines, while the other has Loomis-Pettebone down-draft producers and American Crossley gas engines. The first mentioned plant is not yet in commercial service but other plant has been in daily operation for a considerable length of time and it has given good results. As the company operates both steam and gas engine plants they are in a favorable position to make a comparison between the two types of prime movers.

In a paper read before the Street and Interurban Railway Association, Mr. Windsor, chief engineer of motive, power, of Boston "L" says : "On June 10, 1906, a 30 day test was begun, the conditions being 16 hrs. per day and 70% load factor. Average Pocahontas coal was used at the rate of 1.31 pounds per K.W. hourfor all purposes? The engines can be started in thirty to sixty seconds and Mr. Windser states that for commercial use the fuel consumption is about one half that of a similar steam plant being 1.5 to 1.75 pounds per K.W. hour against 3 to 4 pounds with steam. The gas producing portion of such a plant is simpler, and easierto operate and holds its efficiency better than a steam plant. The gas plant can be put into service in 15 to 20 minutes

The gas plane can be dry ashed service in 10 to 15 minutes
operate can using the efficiency better than a steam driven.
Securing portion of for a plane to engine, an assembly.
per H.W. Your equipment I to a pressure-tight ser. The gas
unit that of a number steam plane being 1.5 to 1.5 pounds
that for commercial two the fuel consumption: to whose one
be operated in ability to whole because and W.Thirteen worker
1.31 pounds per K.W. however mil purposes the engines can
Tractor. average Consumption coal was used on the rate of
was boiler, two conditions being 16 hrs. per day and York load
power', of Boston min ships : "On June 30, 1909, a 30 day test
Copyright © 2019
In a power word boilers are placed and intermediate
between the two types of prime movers.
they are in a favorable position to make a comparison
In the ordinary operation both steam and gas engine plants
considerable length of time and it was given good results.
service but other plant has been in daily operation for a
engines. The first mentioned plant is not yet in commercial
Starting two-cycle gas engines, while the other has insuffi-
of them is equipped with Taylor pressure gas producers and
purpose they built two sections of about 1,000 H.P. each. One
with gas power for supplying its carrying distributor. Per unit

against 1 to 1½ hours with steam plant. Twice a week it takes three hours to remove the ashes but this is no more difficult than the work required around a steam boiler plant.

The water required is considerably less for a gas plant than for a condensing steam plant and considerably more than for a non-condensing steam plant.

At the government fuel testing station, St.Louis (removed to Jamestown since March, 1907) are installed a 235 b.h.p. three cylinder vertical Westinghouse gas engine and two independent pressure gas producers manufactured by R.D.Wood & Co., of Philadelphia. This plant is provided with scrubbers and a rotary tar extractor but the apparatus for removing the sulphur has not been used because it was found that the sulphur in the gas did no harm to the engine so long as water is not injected into the exhaust. 162 tests of about 30 hours each have been made with this plant and it has proved thoroughly reliable. The Taylor producer used was desighed for anthracite coal but has made a remarkable showing on all kinds of bituminous coals and lignites. A summary of the results of these tests on bituminous coals has been condensed from bulletin #290, U.S.Gelogical and is reproduced in table .

At the works of Messrs Rowntree & Co., Ltd., of York two 250 h.p. gas engines are installed. The average calorific value of the bituminous coal used is 12250 B.t.u.

per cu.ft. (by analysis). The fuel consumption in the producer averaged 1.3 lbs per kilowatt hour (three 12 hr. tests).

The engines have run continuously for many weeks, from 7.30 a.m. on Monday until noon Saturday and operate in parallel with steam driven units.

Many other examples of gas engine plants having units of about 250 b.h.p. could be cited, but the above mentioned plants will show that there is no doubt of the modern gas engine being a reliable machine and that we may with perfect confidence select it for our station.

Having now selected the gas engine as our type of prime mover there still remains the question of what particular make of engine and producer it will be advisable to install.

In this work we can make use of a few facts that are pretty well established amoung gas engine engineers,

1. For powers of 200 b.h.p. and over the three cylinder vertical single-acting type is rapidly becoming obsolete and is giving place to the horrizontal, tandem double-acting type.

2. Where the difference in the price of bituminous and anthracite coal is greater than $1.00 per ton, producers using bituminous coal have the lowerst operating expense.

3. For powers larger than 200 h.p. it is advisable to use a pressure system with a gas storage tank.

The Loomis-Pettebone gas generating system is by far the best for use with bituminous coals because it removes the tar without the necessity of installing a mechanical tar extractor. The U.S.Government tests at St.Louis show that producer gas from many bituminous coals contain as high as 300 lb. of tar per ton of coal consumed so the mechanical extraction of the tar for a plant of this size represents a considerable capital outlay as well as about 20 h.p. to drive the extractor and as the by-product tar obtained has little commercial value its calorific value may be counted against the efficiency of the producer.

In the Loomis Pettibone down-draft producers all the gas and tarry matters distilled from the fresh fuel in the uper strata of the fire pass down through the deep fuel bed where the hot fire "crackes" the tar up into a permanent gas and lamp black. The lamp black thus formed does no harm except to dirty the scrubber water.

The hot gas leaves the generator at a point below the grate and passes into the steam boiler where the gas is cooled, giving up its heat to form steam to be used for the steam-blast in the producer. From the boiler the gas passes to the bottom of the wet scrubber. The wet scrubber consists

3. For powers larger than 500 h.p. it is advisable
to use a pressure system with a gas storage tank.

The Doorman-Patterson two pumping system is
by far the best for use with bituminous coals because it
removes the tar without the necessity of installing a mechanical
tar extractor. The U.S.Government tests at St.Louis show that
recovery the five very bituminous coals contain as high as 300
lb. of tar per ton of coal compared to the mechanical extraction
of the tar for a plant of this size represents a considerable
capital outlay as well as about 3% h.p. to drive the extractor
and as the by-product tar obtained has little commercial value
the saleable value may be counted against the efficiency of the
process.

In the Doorman Patterson double pressure gas
and tarry matters distilled from the fresh fuel in the
upper stages of the fire pass down through the deep fuel bed
where the hot fire "coke" the tar up into a permanent gas
and deep layer. The long flame thus formed does no harm except
to carry the moisture water.

The hot gas leaves the generator at a point below
the grate and passes into the steam boiler where the gas is
cooled, giving up its heat to steam used to be used for the
steam-plant in the producer. When the boiler tubes the gas passes
to the bottom of the wet scrubber. The wet scrubber contains

of a steel cylinder provided with coke charged trays and water sprays. From the top of the wet scrubber the gas passes through a positive type exhauster which maintains sufficient vacuum to create a draught through the fires and pressure enough to deliver the gas holder. By this system there is mo danger from leakage of poisonious gas at the producer and the rate of gasification can be controled by regulating the speed of the exhausted. The gas now passes to the dry scrubber which is cylindrical and contains two chambers with tray charged with excelsior or shavings. The chambers are so arranged that one may be cleaned while the other is in operation. The gas is now clean and passes to the gas holders which act as a large thermal reservoir at all times.

The makers of the producer guarantee that with the producers cold thirty minutes is all that is required to kindle and get fires into condition for making gas to the full capacity of the plant. If the generators are shut down for six to four hours, only ten minutes is required to resume making gas.

The smallest down-draft producers made by the Power& Mining CO. are 500 b.h.p. capacity so we will install two of there units and one can be operated at about full load throughout the working day while the other acts as a reserve. For ordinary factory use one producer only would be installed but I am figuring on the extra producer units to secure a reliability of producer plant not equaled by a boiler plant.

or, progress plant not equipped by a boiler plant.

I am writing on the extra pressure order to secure a reliability ordinary service one producer only would be inadequate but out one working day while the other acts as a reserve. Or there units and one can be overhauled or shut down locally throughout 08. the 500 p.p.m. capacity so we will receive two of

The smallest commercial generators made by the Power Power, only two minutes is required to remove melting gas. of the plant. If the generators are shut down for six to four

produces only thirty minutes it will then is required to handle

The makers of the producer gas plant with the gas holders which act as a large storage reservoir at all times. other is in operation. The gas is then drawn off passed to the

The chambers are so arranged that one may be cleaned while the using two chambers with only charges with complete of economy.

new passage to the only carburetor which is efficient and controlled by regulating the speed of the exhausters. The of production gas of the producer and the rate of gasification the gas holder. By this system there is no danger from leakage create a draught through the fires and pressure enough to deliver a positive type exhauster which maintains sufficient vacuum to

sphere. From the top of the rod governor the gas passes through of a steel cylinder provided with coils charged brine and water

In my experience the Munzel engine as made by the Minneapolis Steel & Machine Co. has a very poor speed regulation so we will not consider it here. Refering to table we see the Snow engines are not only of the most advanced design but are cheaper than the three cylinder vertical types. There is still a question as to which of the Snow engines it is most economical to install.

My calculations show that the twin tandem installation will use 58 tons more coal per year than the single tandem but the fixed charges, per year, on the single tandem will be about $600.00 greater so it will be advesable to install the twin tandem as the floor space required is about the same in either case.

Parallel seated quick closing valves are best suited to the work as they are self cleaning and cut-off almost instantly in case of emergency. The engine should exhaust into a cast-iron header under the floor and then to a concrete well outside the building.

In my experience the manual engine as made by the Minneapolis Steel & Machine Co. has a very poor speed regulation so we will not consider it here. Referring to table [illegible] we see the Snow engines are not only of the most advanced design but are [illegible]. They [illegible]

a question as to which of the Snow engines it is most economical to install.

My calculations show that the twin tandem installation will use 88 tons more coal per year than the single tandem but the fixed charges, per year, on the single tandem will be about $600.00 greater so it will be advisable to install the twin tandem as the floor space required is about the same in either case.

Several reasons quick closing valves are best suited to the work as they are self closing and automatic should immediately in case of accident. The engine should exhaust into a condenser under the floor and then to a concrete well [illegible].

The following assumptions have been used in this investigation.

Bituminous coal 13500 B.t.u. per pound.

Evaporation 7.0 #water per lb. coal at and from 212° farh.
Temperature of feed water 200° farh.

For 100 pounds steam pressure and fire-tube boilers,
evaporation factor 1.0523.

For 150 lbs. steam pressure and water tube boilers,
evaporation factor 1.0611

Stand-by losses steam plant 10% of total coal required.
" " gas plant 5% " " " "

Power to drive auxiliaries in percent of total gas or steam required;

Condensing steam plants 15%
Non-condensing steam plants 5%
Producer gas plant 2%

Water required:

30 lbs. water to condense one pound of steam.
200 lbs. water per K.W.H. for gas engine plant.

Producer efficiency 80% or 1.25 lbs. of coal per b.h.p. hour.

Pressure efficiency 90% or 1"Hg lbs. of coal per h.p. hour.

300 lbs. water per H.P.H. for gas engine plant.

90 lbs. water to condense one pound of steam.

Economy two pound %

Power to drive machinery in pairing of hemp ton or steam

" " " one pound " " " " "

Stand-by locomotive steam plant 10% of total cost required.

Air-compressing plant 1:6000.

For 150 lbs. steam pressure use water tube boilers.

For 300 pounds steam pressure use tube-type boilers.

Temperature of feed water 200° here.

Expansion 1:6 $\frac{1}{2}$ water per hp. coal 4# per hour 232° temp.

Minimum cost 12000 B.t.u. per hour.

The following examples have been used in this

Engine efficiency for given load factor,

Snow single tandem gas engine 13500 B.t.u./ b.h.p. hr.

Snow twin '' '' '' 14500 '' / '' ''

Cost of gas engines $54.00 per K.W.

Cost of producers 30.00 per K.W.

Wages,

1 chief engineer	at $	1500	per year.
1 assist. ''	at	1000	'' '' .
2 firemen	at	750	'' '' .
1 laborer	at	600	'' '' .

Engine efficiency for given load factor.

Steam turbine " " " 18000 " \ " "

Cost of gas engines $24.00 per H.P.

Cost of producers 25.00 per H.P.

1 chief engineer at 1500 per year.

1 assist. " at 1000 " "

2 firemen at 720 " "

1 laborer at 600 " "

BIGLIOGRAPHY.

Books:-

Gas-engines,	Hutton.
Practical Treatise on the "Otto"cycle gas-engines,	Norris.
Gas-engines and producer gas plants,	Mathot.
Gas and oil engines,	Clerh.
Practical gas and gasoline engines,	Longanecker.
Gas and petroleum engines,	Robinson.
Gas and oil engines,	Goldingham.
Gas and petroleum engines,	Graffeguy.
Gas, gasoline and oil vapor engines,	Hiscox.
Gas, gasoline and oil engines,	Hiscox.
The gas-engine,	Warmick.
Gas-engines,	Goodeve.
Gas-engines troubles and remedies,	Strittwater.
Ignition devices for gas and petroleum motors,	Bottone.
Gas-engine construction,	Persell&Weed.
Gas-engine design,	Lucke.
Gas and oil engine management,	Bottone.
Care and management of gas engines,	Luckfeld.
Manual for gas engineering,	Lee.
Theory of the gas engine,	Clerk.

Books:-

The steam engine, — Perry.

Gas engine design, — Stoddard.

Gas, oil and air engines, — Donkin.

Text-book on the steam engine, (supplement on gas engines) — Goodeve.

Practical treatise on modern gas and oil engines, — Grover.

Gas Engines:-

Recent development in gas engines,
Engineering, 73 : 697.

Some modern gas engines,
Engineer (London), 99 : 1 supplement.

Development of the gas engine,
Engineer, 42 : 26
Cassier Magazine, 19 : 149

Gas engines,
Power, 24 : 435, 439, 627
Engineer (London), 92 : 425, 438, 474, 484
Engineering, 82 : July, 13.

Large gas engines,
Engineering, 80 : 230, 263, 295
Gas Power, 1 : 38

Gas and oil engines,
Power, Feb. 1900

Modern gas engines,
Ice & Refrigeration, 29 : 59, 105, 139

Munzel gas producer & gas engine,
The Gas Engine, 9 : 108

Korting gas engine,
Railroad Gazette, 34 : 922

Maywood gas engine,
Elec. World, 38 : 829

Gas Engines:-

Recent development in gas engines,
Engineering,

Some modern gas engines,
Engineer (London),

Development of the gas engine,
Engineer,

Gas engines,
Power,
Engineer (London),
Engineering,

Gas power,
Engineering,

Gas and oil engines,
Iron,

Modern gas engines,
Ice & Refrigeration,

Runsey Gas Producer & Gas Engine,
The Gas Engine,

Mavrodo Gas Engine,
Engineering,

Gas Engine Construction,
Engineering,

Gas engine design,

Gas, oil and air engines,

Text-book on the steam engine,
(suppl.vol. on gas engines)

Practical treatise on modern gas and oil engines,

Nash gas engine,
Elec. World, 38 : 740

Vogt gas engine,
Engineering, 77 : 37

Oechelhauser gas engine,
Engineering, 81 : 5, 73, 141, 204

Olds gas power company,
Amer. Mach., 29 : 761

Perkins gas engines,
Amer. Mach., 22 : 386

Westinghouse gas engine,
Electrical World, 34 : 543

Type of 3-cylinder vertical engine,
Engineering News, 42 : 197

Letombe gas engine system,
Engineer (U.S.), 43 : 137

Callahan gas engine,
Engineer, 42 : 138

National gas engine,
Engineer, 42 : 309

San Francisco gas engine elec. plant,
Street Ry. Jour., 25 : 287

Double acting gas engine,
Electrician, 54 : 205

Sibley gas engine,
Sibley Journal, 16 : 69

Heavy duty gas engine, installation,
Iron Age, 77 : 1601

Ehrhardt & Sehmer gas engines,
Iron Age, 78 : Aug.9.

Strang gas engine,
Engineer, 42 : 200

```
'Engineer',
'External gas engine',
'Iron Age',
'Mechanical Science gas engines',
'Heavy duty gas engine, Intelligencer',
'Ideal Journal',
'Simple gas engine',
'Double acting gas engine',
'San Francisco gas engine also, Alert',
'Natural gas engine',
'Gasoline gas engine',
'Engineering News',
'Type of Two-Cylinder vertical engine',
'Electrical World',
'Petroleum gas engines',
'Amer. Mach.',
'Engineering',
'Oscillating gas engine',
'Engineer (U.S.)',
'Telephone gas engine system',
'Engineering News',
'Iron Age',
'Mechanical Engineer',
'Scientific American',
'Steel Engraving',
'Amer. Mach.',
'Engineering',
'Double gas engine',
'Simple gas engine',
'Heavy duty gas engine, Intelligencer',
'Iron Age',
'Mechanical Engineer',
'External gas engine',
```

Cockerill gas engine in America,
Electrical Age, 33 : 464

Diesel engine installation at the Traction Terminal Building, Indinapolis,
Electrical Review, 48 : 457

Nuremberg gas engine,
Engineering, 80 : 585, 586

Nash 125 h.p. gas engine,
Engineering Record, 44 : 432

Mees gas engine,
Engineering Review, 14 : 166

Gas Producers.

Gas producers for power purposes,
Engineering News, 55 : 530

Gas engine and fuel gas producer power plant,
Engineering News, 42 : 334

Gas producers & the Beldt automatic feed device, Pamphlet R.D.Wood & Co. Philadelphia, Pa.

Producer gas for electric power stations,
Cassier's Magazine, 29 : 316

Gas producer plant for electric generating stations,
Electrician, 56 : 1010

Gas producers for power,
Power, 26 : 225

Gas producer systems,
Engineer (U.S.), 42 : 18

Power production by gas producers and engines,
Mechanical Engineer, April 4, 1903

Gas producer power plant,
Journal of Electricity, March, 1906.

Producer gas and gas engine,
Power, April, 1903.

Gas engine and producer gas,
American Engineer, 73 : 350

Producer gas for electric power,
Cassier's Magazine, 29 : 316

New gas producer,
Engineer (London), 96 :578

Gas producers for power,
Power, 24 : 520

Use of producer gas for power generation,
Engineering Record, 53 : 623

Loomis water gas and producer gas process,
Engineering News, 46 : 170

The suction gas producer,
By W.H.Booth,
Cassier's Magazine, 29 : #5 March 1906.

The Koerting suction gas producer,
Electrical Age, 37 : 290

Suction gas producer plant,
Cassier's Magazine, 28 : 392

Suction gas plants,
Electrician, 54 : 1005

Trials of suction gas producer plants,
Power, 26 : 97

Power, 36 : 39

Table of suction gas producer plants, 36 : 39

Suction gas plants
Electrical, 84 : 1008

Suction gas plants
Gasifier Mechanism, 86 : 896

Suction gas producer plant,
Gasifier Mechanism, 86 : 896

The suction gas producer,
Theoretical Age, 41 : 1020

Gasifier Mechanism, 86 : 896 [illegible]

The suction gas producer,
By [illegible]

Engineering News, 16 : 170

Kerosene motor gas and producer
for Power,

Engineering record, 63 : 852

Use of producer gas for power
generation,

Power, 84 : 896

Gas producers for power,

Engineer (London), 86 :896

Gem gas producer,

Double-[illegible]

Producer gas for electric power,

Gas engine and producer gas,

Implane Engines,

Power,

Producer gas and Gas engine,

Journal of Electricity, [illegible]

Gas Producer Power Plant,

POWER PLANTS.

Steam :-

Power plant economies,	
Electrical World,	40 : 438
U.S. Engineer,	37 : 150
Power,	26 : 166
Fuel economies in steam plants,	42 : 235
U.S.Engineer,	
Engineering Magazine,	29 : 127
Cost of water in a large electric power station,	
Electrical Age,	32 : 231
Some figures on the cost of electric power plant,	
Engineering,	70 : 112
Comparative economy of steam and gas power,	
Engineering Record,	49 : 11
Cost of power,	
Engineering Record,	51 : 90
Comparative cost of gas & steam power,	
Engineering Record,	51 : 418
Labor and wages in power plants,	
Power,	23 : 731
Power plant costs,	
Power,	25 : 778
Power plants in factories D.c. vs. poly~~plus~~ phase.	
American Electrician,	12 : 128
Repairs in a power plant,	
U.S. Engineer,	41 : 247, 281, 347, 427
Development of a steam power plant,	
Engineering Record,	47 : 25

Index

Power station design,
Engineering Magazine, 29 : 689, 811
30 : 71, 182

Power plant in a factory,
Engineering Record, 39 : 430

Design and construction of a central station,
Engineering Record, 40 : 651

Design of a power station,
Electric World, 43 : 991, 1030, 1090

Piping a steam plant,
U.S. Engineer, 36 : 78, 117

Operating results of the new Baltimore turbine plant,
Engineering Record, 54 : 475
Power, 26 : 733, 735

Failures in power plants,
Engineering, 78 : 280

Design of steam power plant,
Engineering Record, 41 : 597

Design of steam power plant condensers,
Engineering Record, 43 : 55

Feed water heaters and economies,
Engineering Record, 43 : 224

Gas :-

Gas engine power plants,
Mining Magazine, 10 : 384

Gas engines for power stations,
Western Electrician, 37 : 273

Modern gas engine power plants,
Engineering Record, 53 : 13

Power station design,

Gas engine and fuel gas
gas producer power plant,
Engineering News, 42 : 334

Gas power pumping station for
high-pressure gas distribution,
Engineer (U.S.), 42 : 1

Evolution of Modern Power Stations,
Street Ry. Journal, 24 : 555

Design of city power stations,
Street Ry. Journal, 22 : 282

Gas producer power plant,
Journal of Electricity, March, 1906.

Large gas engine power plants,
C.E. Douglas,
Tech. 2 Ill, 1.7 BP Iron and Coal,
Trades Review, : 283 Jan. 25,07.

Utilization of gas engines in
connection with long distance electrie
trans.
Journal of Electricity, 15 : 312

Gas engine power plant,
Machinery, 11 : 106

Planing & construction of the
power plant,
Engineering Magazine, 32 : 748

Gas power economies,
Iron Age, 77 : 1392, 1462

Gas producer power plants,
Engineer (U.S.), 42 : 474, 712

Power gas & large gas engine
for central stations,
Engineering, 70 : 813

Some gas driven power plants,
Engineering, 70 : 287, 321, 399, 465,
526, 589, 654

Engineering,
Gone gas driven power plants, 10 : 337, 403, 469,
Engineering,
Gas engine and fuel gas
Engineering News,
Engineering News,
Engineering Record,
Engineering Record,
Engineering Magazine,
Engineering Magazine,
Engineering Magazine

Experience of the Boston elevated Railway with gas producer engine plants,
Engineering Record, 54 : Oct. 20, 1906.

Gas producer power plants,
Amer. Inst. Mining Engineers, Feb. 1905.

Gas engine in a modern building,
Power, 25 : 617

Gas driven electric lighting plant,
Engineering, 76 : 416, 417, 420

Aplication of gas power to electric railway survice,
Engineering Record, 52 : 387

Gas and electric power plants,
Engineer (U.S.), 42 : 104

Gas power in electric traction,
Street ry. Journal, 26 : 594

Gas power in the operation of high speed inserurban railroads,
Electrical Age, 37 : 179

Gas power plant at Elderslie Graving Dock,
Engineer (Lond) 98 : 150

Gas power plant at Harpham Harbor,
Power, 25 : 212

San Francisco gas power electric plant,
Street ry. Journal, 25 : 287

Power plant of the Moctezuma Copper Co.,
Amer.Inst.Mining Engineers,Trans. Oct. 1903.

Olds gas power company,
American Mach. 29 : 761

Engineering Record, 14 : 80, 1910.

Gas producer power plants,
Amer. Inst. Mining Engineers, Trans.

Gas engine in a modern building,
Power,

Gas driven electric lighting plant,
Engineering, 112, 430

Application of gas power to electric
railway service,
Engineering Record,

Gas and electric power plants,
Engineer (U.S.),

Gas power in electric traction,
Street Ry. Journal, : 1902

Gas power in the operation of high
speed inverted reciprocating,
Electrical Age, 30 : 252

Gas power plant at Ridgeville
Traction Book,
Engineer (London), 94 : 320

Gas power plant at Baltimore Electric,
Power, 25 : 10

Gas Producer gas power electric
light,
Street Ry. Journal, 19 : 827

Power plants of the Mocoronmo
Copper Co.,
Amer. Inst. Mining Engineers, Trans. Dec. 1908.

Full gas power complex,
Engineering Record, 49 : 1902

Madely water supply operation by gas engine and producer gas,
Engineer (London), 95 : 147

Works of the power and mining machine company,
Engineering Record, 50 : 652

Large Westinghouse gas engines,
Tech.O.3 Prog.age, Feb.15,07, : 113

Gas engines at Pan American, Exposition,
Power, Sept.,1901.

Gas engines at Paris Exposition,
Power, Oct.,1900.

Gas power plant for the Morecanbe Bay Harbor Works,
Engineering Record, 50 : 467

Gas power & heating plant of the Atha Tool Company,
Engineering Record, 52 : 56

Some features of the Warren gas power plants,
Electric Journal, 3 : 205

Power plant at the works of the Power & Mining Machine Co.
Engineer (U.S.), 41 : 829

5000h.p. gas engine of California Gas & Electric Corporation,
Engineering Record, 52 : 372

Comparative cost of gas and steam power,
Engineering Record, 51 : 418

Mechanical efficiency of the gas engine,
Power, 25 : 263
Engineering News, 54 : 121

Efficiency test of 125 h.p. gas engine,
A.S.M.E. 21 : 396

Improving the economy of gas engines,
Power, 25 : 344

Economy of gas producer power plants where heating is necessary,
Engineering News, 54 : 242

Comparative economy of steam and gas power,
Engineering Record, 49 : 11

Gas engine efficiency,
Engineer (U.S.), 43 : Aug.15,1906.

10 h.p. for an hour for one penny,
Electric Engineer, 37 : 406

MISCELLANEOUS.

Cost of energy in fuels,
Journal of elect. power & gas, 28 : 223

Power costs, gas vs. steam engine,
Electric Age, 37 : 211

Various methods of governing 4 - cycle gas engines,
Engineering Magazine, 30 : 355

Gas engines in commercial use,
Mech. Engineers, 17 : 123
Sc. Abstracts, 9 : 341

Regulation of gas engines,
Engineering Magazine, 24 : 216

Gas engine governing and economy,
American Mach., 23 : 37

Gas engine economy,
Engineer, 42 : 35, 75, 139, 171

Design & construction of large gas engines in Europe,
Power, 25 : 738

Power, 56 : 456

Gas engines in Europe, 56 : 456

Engineer, 46 : 96, 196, 796, 1456

Gas engine economy, 46 : 96, 196, 796, 1456

Internal combustion gas engine, 32 : 84

Combustion of gas engine, 32 : 84

Engineering Record, 32 : 84

Engineering News, 32 : 84

Gas engines in connection with electric power, 32 : 84

Engineering Magazine, 30 : 1056

4 - cycle gas engine, 30 : 1056

Various methods of governing, 30 : 1056

Electric Age, 24 : 1152

Power, 24 : 1152

Compressing gas for engines, 28 : 1056

Count of energy in fuel, 28 : 1056

10 H.P. for an hour for one penny, 24 : 456

Electric Engineer, 24 : 456

Engineer (U.S.), 46 : 96, 196, 796, 1456

Gas engine efficiency, 42 : 32

Engineering Record, 42 : 32

Comparative economy of steam and gas power, 44 : 956

Engineering News, 44 : 956

Where heating is necessary, 28 : 856

Economy of gas producer power ([illegible]

Power, 28 : 856

Increasing the efficiency of [illegible]

Progress & experience in the construction of large gas engines,
Engineering, 82 : Nov.,2.

Methods for the starting of the gas engine,
Engineering Magazine, 29 : 559

Design, construction& Application of large gas engines,
Power, 25 : 677, 738
26 : 34

Current practice in gas engine design,
Sibley Journal, 17 : 350

Gasoline engine in irrigation work, (Texas & New Mexico),
Gas Power, 4 : June, 1906.

Gas engines in commercial service,
Engineer (U.S.), 43 : Aug.,15.

Future of Electric supply,
Engineering Magazine, 18 : 837

Gas engine situation in Europe,
American Elec., 16 : 4

New industrial situation,
Power, April 1900.

Evolution of gas power,
Amer. Soc. Mec. Eng. 28 : 163, 194

Commercial production of nitric acid in connection with the opperation of gas engines,
Sibley Journal, 20 : 315

Oils for lubrication of gas engines,
Pages Weekly, 9 : 141
Sc. Abstracts, 9 : Sept.,06.

Progress & experience in the
development of large gas engines',
Engineering', 93 : Nov.'93.

Methods for the starting of
the gas engine',
Engineering Economics', 39 : 595

Design, construction & operation
of large gas engines',
Power', 84
: 844, 1?9

Current practice in gas engine design',
Simply Journal', 17 : 230

Operating engine on Kyllstein gas',
(Verse & Wen Mexico)',
Gas Power', June, 1909.

Gas engines in commercial service',
Engineer (U.S.)', : Aug.'96.

Future of Electric supply',
Engineering Magazine', 12 : 934

Gas engine situation in Europe',
Engineer Bits',

New industrial situation',
Power',

Evolution of Gas Power',
Amer. Mach. Mach. Ency', 98 : 186, 194

Commercial production of electric wold
in connection with the exhaustion of
gas engines',
Mining Journal', 80 : 816

Gas. Abstracts',
Engen Motor', : 1?2
: 6?8, '06.

Gite for Imprestion of Gas engines',

Gas

	Makers,			
	Type,			
1.	Brake Horse Power,			
2.	Speed in R.P.M.,			
3.	Cylinder dimensions,			
4.	Total weight,			
5.	Cost of Engine f.o.b. Factory,			
6.	Cost of Erecting Engine,			
7.	Cost of Piping,			
8.	Cost of Erecting Piping,			
9.	Cost of Starting Device, (Tank + Compressor)			
10.	Cost of Erecting Item 9,			
11.	Guaranteed B.t.u./b.h.p./hr. Full			
12.	" " " " 3/4			
13.	" " " " 1/2			
14.	" " " " 1/4			
15.	Over-load for two hours,			
16.	Loss in Speed at this Over-load			
17.	Speed varation with varying			
18.	Method of governing,			

19.	Weight of Engine,			
20.	Cost of Engine,			
21.	Foundations,			
22.	Cost of Foundations, @ $2.35/c			
23.	Cost of Erecting + Accessories,			
24.	Total Cost,			

Table No. I.

Gas Engines — Fuel to be Producer Gas 140 B.tu/cu.ft.

	Makers,	Westinghouse Machine Company	Snow Steam Pump Co.	Snow Steam Pump Co.	S.M. Jones Co. Rathbun Engine	Minneapolis Steel + Machinery Co.
	Type,	3 cyl. Vertical Single Acting four-Cycle	Single Tandem Double Acting four-Cycle	Twin Tandem Double Acting four-Cycle	3 cyl. Vertical Single Acting four-cycle	Twin Horizontal Single Acting four-cycle
1.	Brake Horse Power,	270	250	250	270	250
2.	Speed in R.P.M.,	200	160	208	225	180
3.	Cylinder dimensions, in.	19 x 22	18 x 30	14¾ x 18	19½ x 19	20¾ x 32
4.	Total weight, lbs.	115000	94500	57500	83000 including Compressor.	—
5.	Cost of Engine f.o.b. Factory, $	14000	10900	9550	11750	10000
6.	Cost of Erecting Engine, $	1300	1000	* 500.	300	300
7.	Cost of Piping, $		500	600	—	
8.	Cost of Erecting Piping, $				—	
9.	Cost of Starting Device. (Tank + Compressor) $	400	500	500	Included with Engine Price.	Included with Engine
10.	Cost of Erecting Item 9, $		50	50		Included with Engine
11.	Guaranteed B.t.u./b.h.p./Hr. Full load,	11500	12500	13600	10000	10000
12.	" " " " ¾ "	12800	13800	14800	11000	—
13.	" " " " ½ "	15700	16150	17400	13000	—
14.	" " " " ¼ "	—	18500	19800	21000	—
15.	Over-load for two hours,	10%	10%	10%	20%	10%
16.	Loss in Speed at this Over-load,	3%	None	None	None	2½%
17.	Speed Varation with Varying Loads,	2%	3%	2½%	2%	2%
18.	Method of governing,	Throttling gas and Air.	Throttling gas + air, also spark.	Throttling gas + air, also spark	Throttling and Automatic timing.	Throttling Mixture of gas + Air

Per Kilowatt.

19.	Weight of Engine, lbs.	575	506	308	415	—
20.	Cost of Engine, $	70.00	58.40	51.10	58.75	53.60
21.	Foundations, cu. yds.	0.5	.48	.214	.47.5	1.49
22.	Cost of Foundations, @ $2.35/cu.yd. $	1.17	1.13	0.50	1.11	3.50
23.	Cost of Erecting + Accessories, $	6.50	11.51	8.85	about 5.50	about 5.50
24.	Total Cost, $	77.67	71.04	60.45	65.36	62.60

* Can be shipped partly erected.

Table No. I.

Gas Engines. Fuel to be Producer Gas.

	Makers.			
	Type.	Vertical Single Acting Four-Cycle	Single Tandem Double Acting Four-Cycle	Twin Tandem Four-Cycle
1.	Brake Horse Power	250	375	
2.	Speed in R.P.M.,	240	180	
3.	Cylinder dimensions, in.	17 × 22	17 × 20	
4.	Total weight, lbs.	115000	194000	
5.	Cost of Engine f.o.b. factory, £	1400	1900	
6.	Cost of Erecting Engine, £			
7.	Cost of Piping, £			
8.	Cost of Erecting Piping, £			
9.	Cost of Starting Device (Tank & compressor) £			
10.	Cost of Erecting Items 8, £			
11.	Guaranteed B.H.P. in Full Load	250	375	
12.	" " " " ¾ "	187½	281¼	
13.	" " " " ½ "	125	187½	
14.	" " " " ¼ "	62½	93¾	
15.	Over-load for two hours,	10 %	10 %	
16.	Loss in Speed at this Over-load,	3 %	3 %	
17.	Speed variation with varying Loads	2 %	2 %	
18.	Method of governing,	Throttling gas & air, also Speed	Throttling gas & air, also Speed	

Per Kilowatt.

19.	Weight of Engine, lbs.	5·75	5·2	
20.	Cost of Engine, £	5·60	5·07	
21.	Foundations, Cu. yds.	0·8	0·53	
22.	Cost of Foundations, £	1·12	0·75	
23.	Cost of Erecting & Accessories, £	1·20	0·80	
24.	Total Cost, £	7·92	6·62	

* Can be obliged

Makers,			
Location,			
Name,			
Type,			
Producer rating,			
Over-load for two hours,			
Guaranteed Eff. Full load,			
" " 3/4 "			
" " Over-load,			
Cost of Plant f.o.b. Factory,			
Cost of Erecting,			
Total weigh of Plant,			
Foundations,			
Floor Space Required,			
Frequency of Charging,			
Effective Grate Area,			
Power to drive Auxiliaries,			
Kind of Fuel Used,			

Weight of Producer,			
Cost of Producer,			
Cost of Erecting,			
Effective Grate Area,			
Total Cost,			

Table No. 1

Gas Engines. Fuel to be Producer Gas.

	Makers.	Westinghouse Machine Company	Snow Steam Pump Co.	Snow Steam Pump Co.
	Type	Vert. Single Acting Tandem Compound	Horiz. Single Acting Tandem Compound	Horiz. Single Acting Tandem Compound
1.	Brake Horse Power	250	250	250
2.	Speed in R.P.M.	200	250	250
3.	Cylinder dimensions, in.	17 & 25	16 & 24	16 & 24
4.	Total weight, lbs.	115 000	94 500	94 500
5.	Cost of Engine f.o.b. factory, $	4 000	4 000	4 000
6.	Cost of Erecting Engine, $	1200	1 000	1 000
7.	Cost of Piping, $		250	250
8.	Cost of Erecting Piping $		150	150
9.	Cost of Starting Device. (Tank + compressor) $		500	500
10.	Cost of Erecting Item 9, $		100	100
11.	Guaranteed Gals. per H.P. per hr. full load,	1.3	1.2	1.2
12.	" " " " " ¾ " "	1.4	1.3	1.3
13.	" " " " " ½ " "	1.5	1.4	1.4
14.	" " " " " ¼ " "	———	———	———
15.	Over-load for two hours,	25%	25%	25%
16.	Loss in Speed at this Over-load,	3%	Nihil	Nihil
17.	Speed Variation with varying Loads,	2%	2%	2%
18.	Method of governing	Throttling gas + air	Throttling gas + air	Throttling gas + air

For Wyoming

19	Weight of Engine, lbs.	57 500	47 000	47 000
20	Cost of Engine, $	12 000	9 000	9 000
21	Foundations, cu. yds.	80	60	60
22	Cost of Foundations, $	400	300	300
23	Cost of Erecting & Accessories, $	2 000	1 500	1 500
24	Total Cost, $	14 400	10 800	10 800

* Can be shipped

Table No. II.

Producer Gas Units Available.

Makers,		R.D. Wood & Co.	Power, Mining & Machinery Co.	Smith Gas Power Co.	Cone Gas Machinery Co.	Minneapolis Steel & Mach. Co
Location,		Philadelphia Penn.	Cudahey Wis.	Lexington Ohio	Detroit Wis.	Minneapolis Minn.
Name,		Taylor	Loomis-Pettibone	Smith	Cone	Munzel.
Type,		Pressure	Dawn-draft.	Suction	Suction	Suction
Producer rating,	h.p.	250	500	235	250	250
Over-load for two hours,	%	10	50	50	20	25
Guaranteed Eff. Full load,	%	68	80	83	85	80
" " 3/4 "	%	65	80	78	75-80	75
" " Over-load,	%	68	80-84	83	85	70
Cost of Plant f.o.b. Factory,	$	15000	12500	3000	4700	5000
Cost of Erecting,	$	1200.0	2500	600	———	200
Total weigh of Plant,	lbs.	140000	162500	34800	40000	50000
Foundations,	Cu.ft.	———	———	170	Good Concrete Floor.	200
Floor Space Required,	sq.ft.	———	———	110	125	175
Frequency of Charging,	hrs.	Depends on Conditions & Coal.	———	6	2	2 to 3
Effective Grate Area,	Sq.ft.	———	———	23.19	19.7	17.4
Power to drive Auxiliaries,	h.p.	5	———	None	4	3
Kind of Fuel Used,		Bituminous	Bituminous	Anthracite #1 Buckwheat	Soft Coal	Anthracite, Coke or Charcoal

Per Kilowatt.

Weight of Producer,	lbs.	750	435	222	214	268
Cost of Producer,	$	80.70	32.20	17.30	25.20	26.80
Cost of Erecting,	$	6.44	6.70	3.43	———	1.08
Effective Grate Area,	Sq.ft.	———	———	0.132	0.1055	0.0935
Total Cost,	$	86.84	38.90	20.73	———	27.88

Table No. II.

Producer Gas Units Available.

Makers.	R.D. Wood & Co	Power Plant Co. & Machinery Co.	Smith Penn
Location.	Philadelphia. Penn.	Cedarburg Wis.	Lapi Ohi
Name	Taylor	Loomis-Pettibone	Sm
Type.	Pressure	Down-draft.	Suc
Producer rating. H.P.	2500	500	2
Over-load for two hours. %	100	50	5
Guaranteed Eff. Full load. %	65	80	8
" " ¾ " %	67	80	7
" " Over-load. %	68	80-84	8
Cost of Plant f.o.b. Factory. $	15000	12500	90
Cost of Erecting. $	12000	2500	[illegible]
Total weight of Plant. lbs.	140000	105400	90
Foundations. Cub.	———	———	[illegible]
Floor Space Required. Sq. ft.	———	———	11
Frequency of Charging. Hrs.	———	———	6
Effective Grate Area. Sq. ft.	———	———	23
Power to drive Auxiliaries. H.P.	25	———	Non
Kind of Fuel Used.	Bituminous	Bituminous	Anth Pea

Per Kilowatt.

Weight of Producer. lbs.	7.50	4.35	2.5
Cost of Producer. $	8.40	32.20	17.
Cost of Erecting. $	6.44	6.70	3.
Effective Grate Area. Sq.ft.	———	———	0.1
Total Cost. $	35.84	38.90	20

1.	Type of				
2.	Size of U				
3.	Number				
4.	Lbs. of				
5.	Cost of				
6.	Cost of				
7.	Cost of				
8.	Cost of				
9.	Cost of				
10.	Cost of				
11.	Cost of				
12.	Cost of				
13	Boiler H				
14.	Numbe				
15.	Type o				
16.	Size of				
17.	Cost o				
18.	Cost o				
19.	Cost of				
20.	Cost of				
21.	Cost of				
22.	Cost of				
23.	Cost of				
24.	Total				

Table No. II.

Producer Gas Units Available.

Makers.	R.D. Wood & Co.	Power Mining & Machinery Co.	South Penn
Location.	Philadelphia, Penn.	Cudahy, Wis.	Larin Ohio
Name.	Taylor	Loomis-Pettibone	Shu
Type.	Pressure	Down-draft.	Suc
Producer rating, H.P.	250	500	8
Over-load for two hours, %	10	50	5
Guaranteed Eff. Full load, %	18	80	8
" " ¾ " %	17	80	7
" " Over-load, %	18	80-84	8
Cost of Plant f.o.b. Factory, $	13000	15000	30
Cost of Erecting, $	1300	2500	3
Total weigh of Plant, lbs.	140000	165500	36
Foundations, Each			17
Floor Space Required, sq.ft.			11
Frequency of Charging, hrs.	Depends on Conditions.		6
Effective Grate Area, sq.ft.			23
Power to drive Auxiliaries, H.P.	3		Non
Kind of Fuel Used,	Bituminous	Bituminous	Anth Pa

For Kilowatt

Weight of Producer, lbs.	7.50	4.25	22
Cost of Producer, $	8.07	12.20	14
Cost of Erecting, $	6.44	4.70	3
Effective Grate Area, sq.ft.			0.1
Total Cost, $	81.84	18.70	20

Table No. III

Cost of Steam Installation with Various Types of Units.

650 B.h.p. Plant.

	Type of Plant,	Simple H.S. Non. Cond.	Compound H.S. Non. Cond.	Compound H.S. Cond.	Vertical L.S. Comp. Cond.	Horizontal L.S. Comp. Cond.	De Laval Turbine	Parson's Turbine
1.	Type of Plant,	Simple H.S. Non. Cond.	Compound H.S. Non. Cond.	Compound H.S. Cond.	Vertical L.S. Comp. Cond.	Horizontal L.S. Comp. Cond.	De Laval Turbine	Parson's Turbine
2.	Size of Units,	240	240	240	240	240	200	600
3.	Number of Units,	3	3	3	3	3	4	2
4.	Lbs. of Steam per i.h.p. per hr.	32	25	21	15	15	18	14
5.	Cost of Engines,	8400	13000	13000	23600	16000	25300	35000
6.	Cost of Generators,	8000	8000	8000	8400	8400		
7.	Cost of Steam Pipes,	3600	3600	3600	4000	4000	3600	4200
8.	Cost of Condensers,	———	———	4800	3700	3700	4500	5100
9.	Cost of Engine House,	3100	3700	3700	4600	6800	2000	1800
10.	Cost of 10 ton Hand-crane,	1000	1000	1000	1000	1000	1000	1000
11.	Cost of Switch-board,	1650	1650	1650	1650	1650	1720	1580
12.	Cost of Foundations,	1300	1800	1800	1800	1800	1450	2000
13.	Boiler h.p. Required,	500	400	356	225	225	339	230
14.	Number of Boilers,	5	4	4	3	3	4	3
15.	Type of Boilers,	Fire tube	Fire tube	Fire tube	Water tube	Water tube	Fire tube	Water tube
16.	Size of Boilers,	120	120	100	100	100	100	100
17.	Cost of Boilers,	6000	4800	4000	5400	5400	4000	5400
18.	Cost of Duplicate Feed Pumps,	1350	1280	1100	900	900	1100	900
19.	Cost of Feed-water Heaters,	540	430	430	380	280	370	280
20.	Cost of Stack,	2280	2100	1730	1400	1400	1730	1400
21.	Cost of Boiler Settings,	2400	2100	1800	1550	1550	1800	1550
22.	Cost of Coal and Ash Conveyor,	3700	3500	3000	2800	2800	3000	2800
23.	Cost of Boiler House,	7680	7440	7250	6400	6400	7200	6400
24.	Total Cost,	51000	53450	56860	67580	62080	58570	69410

Table No. III.

Cost of Steam Installation with

650 B.H.p. Tri

Type of Plant.	Simple H.S. Non. Cond.	Compound H.S. Non. Cond.	Compound H.S. Cond.
Size of Units,	240	240	240
Number of Units,	3	3	3
Lbs. of Steam per i.h.p. per hr.	32	25	21
Cost of Engines,	8400	13000	13000
Cost of Generators,	8000	8000	8000
Cost of Steam Pipes,	3600	3600	3600
Cost of Condensers,	———	———	4500
Cost of Engine House,	3100	3700	3700
Cost of 10 ton Hand-crane,	1000	1000	1000
Cost of Switch board,	1850	1850	1850
Cost of Foundations,	1300	1800	1800
Boiler h.p. Required,	5000	4000	3400
Number of Boilers,	5	4	4
Type of Boilers,	Fire tube	Fire tube	Fire tube
Size of Boilers,	120	120	100
Cost of Boilers,	6000	4800	4000
Cost of Duplicate Feed Pumps,	1350	1250	1100
Cost of Feed-water Heaters,	540	540	450
Cost of Stack,	2250	1800	1650
Cost of Boiler Settings,	2400	1800	1800
Cost of Coal and Ash Conveyor,	2700	2700	2700
Cost of Boiler Mains,	1620	2430	2430
Total Cost,	51000	52800	52800

Table No IV.

Cost of Gas Power Installation,

Snow twin tandem engines - Loomis-Pettibone Producers.

650 b.h.p. Plant.

25.	Engines,	$	28000
26.	Dynamos,	$	8400
27.	Foundations,	$	300
28.	Piping,	$	1000
29.	Switchboard,	$	1650
30.	10 Ton Hand-crane,	$	1000
32.	Motor-Generator & Storage Battery,	$	300
33.	75000 Cu.ft/hr. Gas Meter,	$	510
34.	Engine House,	$	6600
35.	Gas Producers,	$	22000
36.	Coal Conveyor,	$	1800
37.	Producer House,	$	4000
38.	20000 Cu.Ft. Steel Gas Holder	$	4800
31.	Air Compressors,	$	800

Table No IX

Cost of Gas Power Installations

Snow twin tandem engines - Loomis-Pettibone Producers

450 B.H.P. Plant

25.	Engines,	2	25000
26.	Dynamos,	2	6400
27.	Foundations,	1	3 00
28.	Piping,	1	1000
29.	Switchboard,	1	1520
30.	10 Ton Hand-crane,	1	1000
31.	Water-Generator-Storage Battery,	1	300
32.	75000 Cu.ft/hr Gas Meter,	1	810
33.	Engine House,	1	6000
34.	Gas Producers,	1	23000
35.	Coal Conveyor,	1	1800
37.	Producer House,	1	4000
38.	50000 Cu.ft. Steel Gasholder	1	4800
39.	Air Compressors,	1	300

Type of				
Total Co				
Interest				
Taxes or				
Insura				
Depreci				
"				
Depreci				
"				
Depreci				
"				
Upkeep				
"				
Upkeep				
"				
Upkeep				
"				
Stoking				
Oil & Su				
Total Fi all exper				
Coal Fo				
Coal Fo				
Coal Fo				
Total C				
Totat W				
Cost o				
Cost o				
Cost of				
Averag				

Table No IX

Cost of Gas Power Installations

Snow Twin Junction engines - Loomis-Pettibone Producers

450 B.H.P. Plant

25	Engines,	2	28000
26.	Dynamos,	1	8400
27	Foundations,	1	3 00
28.	Piping,	1	1000
29.	Switchboard,	1	1620
30.	10 Ton Hand-crane	1	1000
31.	Main Generator-Storage Battery,	1	350
32	73000 Cu.ft/hr Gas Meter	1	310
33.	Engine Floor,	1	6500
34.	Gas Producers	2	12000
35.	Coal Conveyor,	1	1800
37.	Producer House,	1	4200
38.	25000 Cu.ft Steel Gas Holder	1	4000
39.	Air Compressors,	1	800

Table No. V.

Annual Running Expense. 10 hours per day, 310 days/year. Average load 300 K.W.

Type of Plant,	Simple H.S. Non. cond.	Compound H.S. Non. Cond.	Compound H.S. Cond.	Vertical L.S. comp. cond.	Horizontal L.S. Comp. Cond.	Delaval Turbine	Parsons Turbine	Snow Gas Engines Loomis-Pettibone
Total Cost of Station, $	51000	54450	56860	67580	62080	58570	69410	81160
Interest on Capital at 5% $	2550.00	2722.50	2843.00	3379.00	3104.00	2928.50	3470.50	4058.00
Taxes on ¾ Cost at 1% $	382.30	408.00	426.00	507.00	466.00	440.00	520.00	609.00
Insurance at ½% $	255.00	272.25	284.30	337.90	310.40	292.85	347.05	405.80
Depreciation 7% on Items,	(4 to 9) (17 to 20) (21, 22)	(4 to 9) (17 to 20) (21, 22)	(4 to 9) (17 to 20) (21, 22)	(4 to 9) (17 to 20) (21, 22)	(4 to 9) (17 to 20) (21, 22)	(4 to 9) (17 to 20) (21, 22)	(4 to 9) (17 to 20) (21, 22)	25, 26, 27, 31, 32, 36,
" $	2379.30	2573.20	2781.10	3351.10	3082.10	3042.90	3852.10	2821.00
Depreciation 5% on Items,	(10)	(10)	(10)	(10)	(10)	(10)	(10)	30, 33, 35, 38,
" $	50.00	50.00	50.00	50.00	50.00	50.00	50.00	1410.50
Depreciation 3% on Items,	9, 11, 12, 20, 23	9, 11, 12, 20, 23	9, 11, 12, 20, 23	9, 11, 12, 20, 23	9, 11, 12, 20, 23	9, 11, 12, 20, 23	9, 11, 12, 20, 23	27, 29, 34, 37
" $	480.30	470.70	483.90	385.50	541.50	423.00	295.40	376.00
Upkeep & Repairs on Items, 3%	(4 to 9) (17 to 20) (21, 22)	(4 to 9) (17 to 20) (21, 22)	(4 to 9) (17 to 20) (21, 23)	(4 to 9) (17 to 20) (21, 23)	(4 to 9) (17 to 20) (21, 23)	(4 to 9) (17 to 20) (21, 22)	(4 to 9) (17 to 20) (21, 23)	25, 26, 27, 31 32, 35, 36
" " $	1019.70	1102.80	1191.90	1521.90	1320.90	1304.10	1650.90	1869.00
Upkeep & Repairs on Items, 2%	(10, 11)	(10, 11)	(10, 11)	(10, 11)	(10, 11)	(10, 11)	(10, 11)	29, 30, 33, 36
" " $	53.00	53.00	53.00	53.00	53.00	544-0	51.60	159.20
Upkeep & Repairs on Items, 1%	9, 12, 20, 23	9, 12, 20, 23	9, 12, 20, 23	9, 12, 20, 23	9, 12, 20, 23	9, 12, 20, 23	9, 12, 20, 23	27, 34, 37
" " $	143.00	140.40	144.80	112.00	164.00	123.80	126.00	109.0
Stoking, Engine-driving & Supervision	4600	4600	4600	4600	4600	4600	4600	4600
Oil & Supplies,	2600	2600	2600	2600	2600	2600	2600	2600
Total Fixed Charges, (including all expense except fuel & water)	14369.60	14852.45	15313.20	16985.40	16127.90	15735.75	17437.65	19016.70
Coal for Engines, Tons.	3580	2780	2345	1700	1700	2021	1587	846
Coal For Standby Losses, "	358	278	235	170	170	202	158	42
Coal For Auxiliaries, "	179	139	362	255	255	303	237	18
Total Coal used per year, "	4117	3197	2942	2125	2125	2526	1982	906
Total Water used per year lbs.	47×10^6	37.2×10^6	935×10^6	694.2×10^6	694.2×10^6	826×10^6	647×10^6	180×10^6
Cost of Coal per year, $	12351	9593	8826	6375	6375	7578	5946	2718
Cost of Water per year, $	47	37.20	935	694.2	694.2	826	647	180
Cost of Power per year, $	26767.60	24482.65	25074.40	24054.60	23197.10	24140.55	24030.65	21914.70
Average Cost of Power/K.W.H. $	.002875	.00263	.0027	.00259	.00249	.002591	.002587	.002361

Table

Annual Running Expense

		Simple H.S. Mean Const.	Compound H.S. Mean Const.	C.
Type of Plant,				
Total Cost of Station,	£	3100 0	3440 0	
Interest on Capital at 3%	£	3120.00	3212.0	
Taxes on £ Cost at 1%	£	382.30	409.00	
Insurance at ½%	£	215.00	218.25	
Depreciation 7% on Items,	£	2211.30	2311.0	
"	£	(1)	(1)	
Depreciation 5% on Items,	£	50.00	70.00	
"	£	1	1	
Depreciation 3% on Items,	£	80.30	120.70	
"	£	1	1	
Upkeep & Repairs on Items, 7%	£	1	1	
" "	£	1	1	
Upkeep & Repairs on Items, 5%	£	1	1	
" "	£	1	1	
Upkeep & Repairs on Items, 3%	£	1	1	
" "	£	1	1	
Working Expenses during Supervision	£	1	1	
Oil & Supplies,	£	1	1	
Total fixed Charges, (including all expense except fuel & water)	£	1	1	
Coal for Engines, Tons.		1	1	
Coal for Standby Losses, "		1	1	
Coal for Auxiliaries, "		1	1	
Total Coal used per year, "		1	1	
Total Water used per year, lbs.		1	1	
Cost of Coal per year,	£	1	1	
Cost of Water per year	£	1	1	

Cost of Power per year,	£	1	1
Average Costed Power (H.P.)	£	1	1